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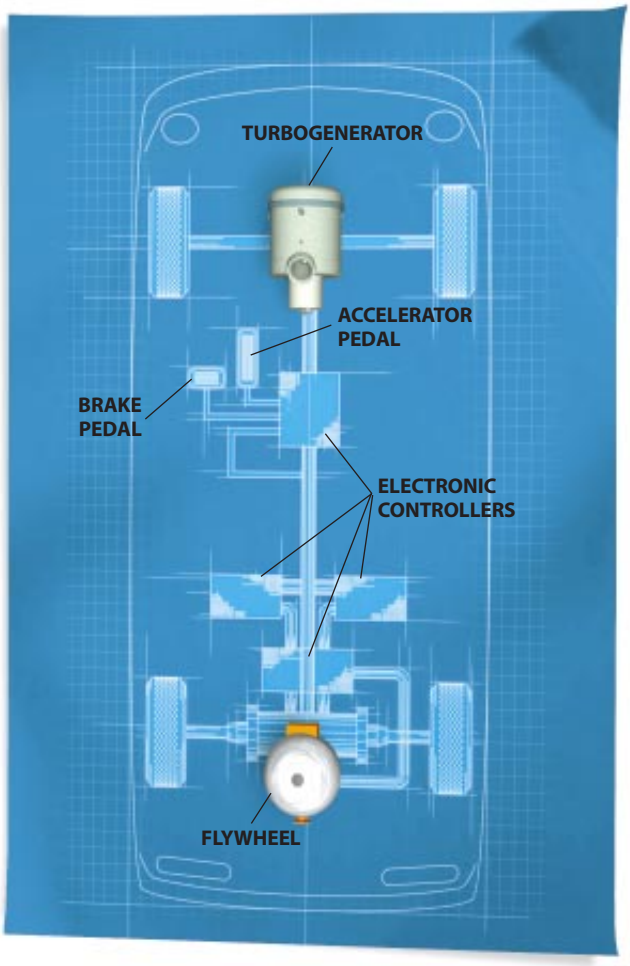
Flywheels in Hybrid Vehicles

A rapidly spinning flywheel combines with a gas-turbine engine to power a novel hybrid electric vehicle

by Harold A. Rosen and Deborah R. Castleman



SLIM FILMS

TURBINE-FLYWHEEL CAR responds when the driver steps on the accelerator or the brake, prompting electronic controllers to divert power from, or to, the flywheel or the turbogenerator. The flywheel supplies most of the power for acceleration and absorbs energy otherwise lost during braking; the turbogenerator is mostly used during cruising and for maintaining the flywheel at its optimum speed.

The search for an alternative to the internal-combustion engine used in today's cars is motivated by two societal concerns: the need to reduce fossil-fuel consumption and the need to reduce air pollution. Unfortunately, most car buyers do not make their purchases based on these criteria. Instead, when looking for a new automobile, most consumers consider issues such as cost, safety, performance and fuel efficiency. (This last factor does, of course, have an effect on fuel consumption and pollution, but it is rarely a car buyer's primary concern.)

In 1993 one of us (Rosen), along with his brother, Benjamin, founded Rosen Motors with the goal of producing a new type of powertrain for cars that would not only address concerns about pollution and fuel efficiency but would also be something that consumers would actually want to own.

Over the past four years, Rosen Motors has been developing a hybrid vehicle that incorporates a rather unusual technology—the flywheel. Although the concept of a flywheel is quite simple, the implementation has been difficult. The flywheel in our powertrain consists of a spinning cylinder made of a high-strength, carbon-fiber composite that can both store and generate energy. The faster the flywheel spins, the more energy it retains. Energy can be drawn off as needed by slowing the flywheel.

Like all hybrids, the automobile developed at Rosen Motors draws power from two separate sources. In our hybrid, we use a flywheel and a gas-turbine engine that is akin to a miniature jet engine. [For an overview of the technology behind hybrids, see "Hybrid Electric Vehicles," by Victor Wouk, page 70.] Both the flywheel and the turbine have electric generators attached; we refer to the combination of the turbine and the generator as a turbogenerator.

These two power sources are better than one internal-combustion engine. High-power internal-combustion engines found in today's cars provide high acceleration but poor fuel economy, whereas low-power engines yield better fuel economy but poor acceleration. In addition, noxious emissions are an unavoidable by-product of operation.

In the hybrid electric powertrain developed at Rosen Motors, the turbogenerator propels the car while cruising, and it also recharges the flywheel, which we use to supply bursts of power for acceleration. In addition, the flywheel has been set up so that during braking it will recover energy that would otherwise be lost to friction.

The advantages of the flywheel lie mainly in its efficiency: chemical batteries that could generate and recapture the same power as the flywheel would weigh considerably more and would recover and reuse only half as much energy during stop-and-go driving. Furthermore, when the flywheel, rather than the combustion engine, is used to supply power for acceleration, the peak power required from the engine drops. As a result, the turbine engine can be smaller and lighter.

We selected a gas turbine because the system emits inherently low levels of pollutants; indeed, these emissions approach zero when catalytic combustion is used. The turbogenerator can be small and relatively simple and thus will have a long, reliable service life. The turbine runs on unleaded gasoline, so car owners can use existing gasoline stations.

On January 5 of this year, we watched the first successful test drive of a turbine-flywheel-powered automobile. We are now working on improved versions of the flywheel, turbogenerator and other components of the powertrain. In the near future we plan to operate the hybrid powertrain in a converted luxury sports sedan to demonstrate the acceleration, fuel economy and low emissions that are possible with the Rosen Motors turbine-flywheel-powered hybrid electric vehicle.

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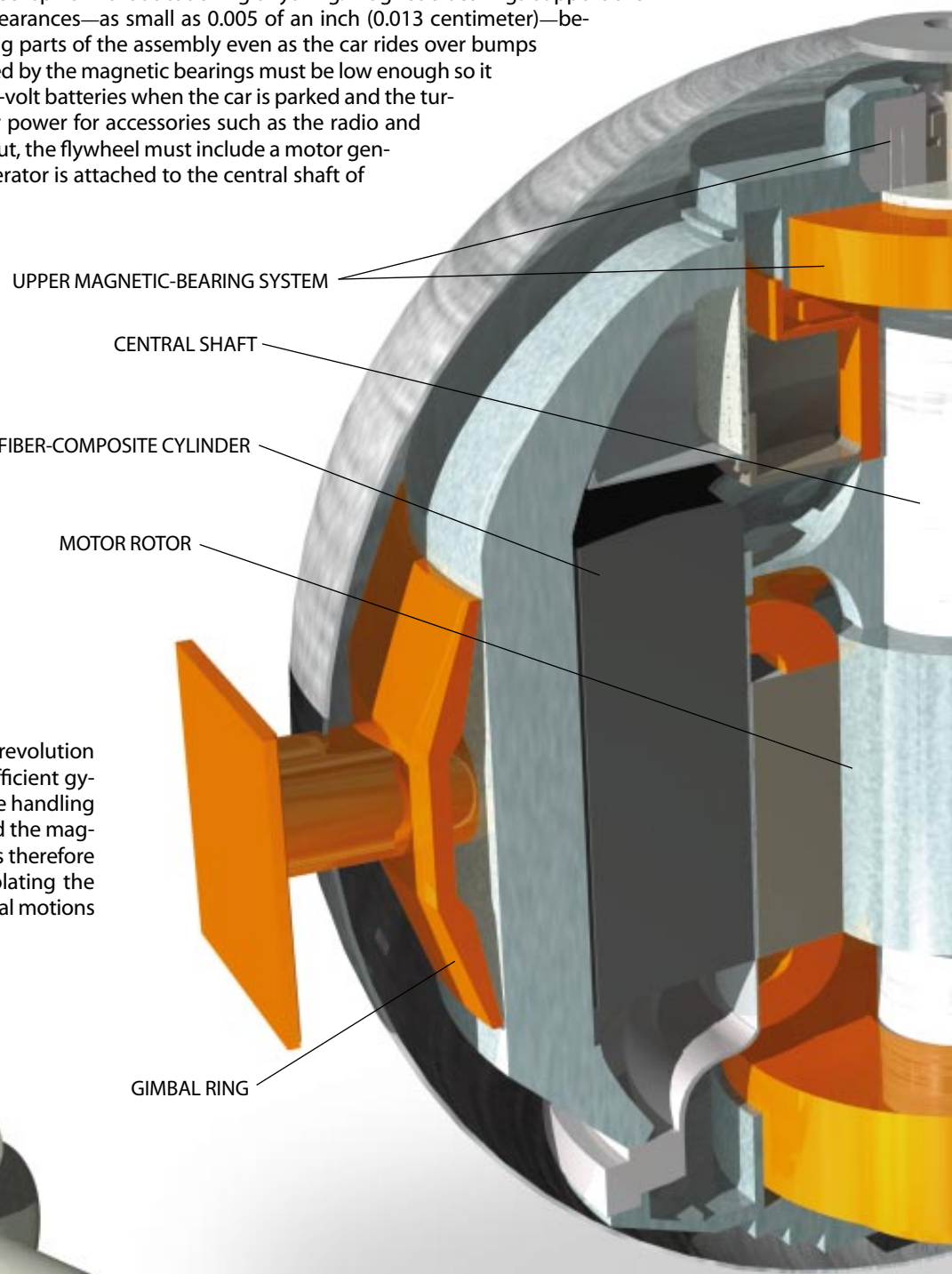
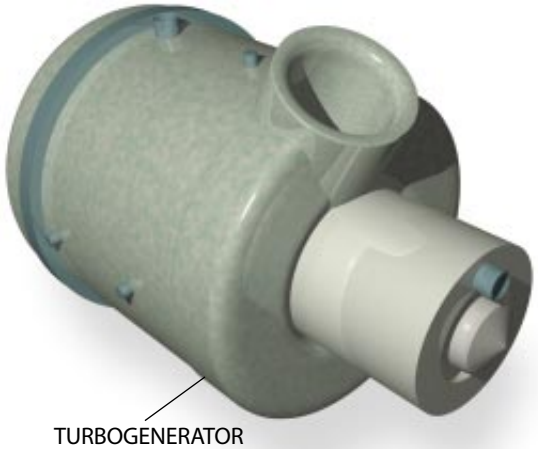
The Flywheel and How It Works

MAGNETIC BEARINGS The flywheel designed by Rosen Motors is made of a titanium hub and a high-strength, carbon-fiber-composite cylinder that can spin as fast as 60,000 revolutions per minute. To reduce friction at these speeds, the flywheel spins without touching anything. Magnetic bearings support the flywheel and preserve the tight clearances—as small as 0.005 of an inch (0.013 centimeter)—between the rotating and nonrotating parts of the assembly even as the car rides over bumps and potholes. The energy consumed by the magnetic bearings must be low enough so it does not discharge the vehicle's 12-volt batteries when the car is parked and the turbine is off. (These batteries supply power for accessories such as the radio and headlights.) To get energy in and out, the flywheel must include a motor generator; the motor rotor of the generator is attached to the central shaft of the flywheel cylinder.



GIMBALS Theoretically, the rapid revolution of the flywheel could generate sufficient gyroscopic forces to interfere with the handling of the vehicle as well as to overload the magnetic bearings. A system of gimbals therefore cradles the flywheel assembly, isolating the spinning cylinder from the rotational motions of the vehicle.



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TURBOGENERATOR The turbogenerator, which is being developed by Capstone Turbine Corporation in Tarzana, Calif., consists of a clean-burning gas turbine (the type of engine used in jets) that drives an internal electric generator. Energy from the turbogenerator is used to keep the flywheel spinning at the proper speed. This turbogenerator is an advanced version of the turbogenerators now in production at Capstone for such applications as auxiliary power generators for buildings.

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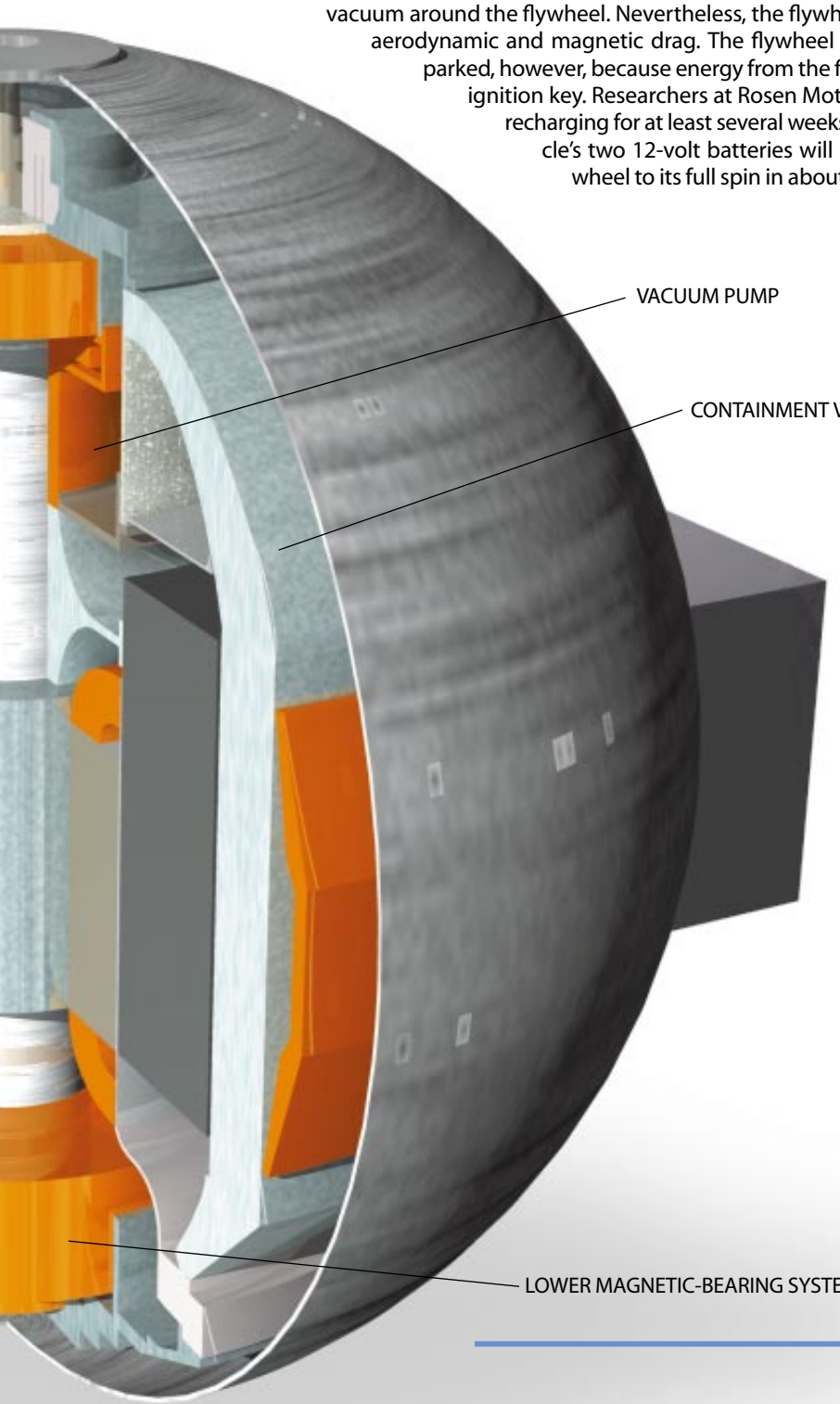
VACUUM PUMP Because aerodynamic drag can slow the flywheel and generate a considerable amount of heat, a vacuum pump consisting of a lightweight molecular drag pump and molecular sieves maintains a vacuum around the flywheel. Nevertheless, the flywheel will lose energy over time as a result of residual aerodynamic and magnetic drag. The flywheel should remain spinning even when the vehicle is parked, however, because energy from the flywheel starts the turbine when the driver turns the ignition key. Researchers at Rosen Motors are developing a flywheel that will run without recharging for at least several weeks. In the event the flywheel does run down, the vehicle's two 12-volt batteries will start the turbine, which will then recharge the flywheel to its full spin in about two minutes.



CONTAINMENT VESSEL For safety reasons, every high-speed rotating system, from huge jet engines to smaller flywheels, must be properly encased. Otherwise, in the unlikely event that the system breaks down, debris would be sent flying outward with considerable force. Workers at Rosen Motors have created a containment vessel of carbon-fiber-composite reinforced steel that will safely contain the flywheel in case of failure. Should such an event occur, the gimbal supports will pull away, allowing the containment vessel to spin to a stop in a cooling liquid that surrounds it. In that way, the flywheel can dissipate its energy relatively slowly, rather than imparting a sudden jerk to the vehicle.

In case of a crash, the containment structure will remain intact because it is designed to withstand the forces released if the flywheel breaks, which are much higher than the forces encountered during a collision. The containment structure itself is anchored to the car with Kevlar-reinforced, high-strength straps.

The Authors

HAROLD A. ROSEN and DEBORAH R. CASTLEMAN both work at Rosen Motors in Woodland Hills, Calif. Rosen is president, chief executive officer and co-founder (with his brother, Benjamin M. Rosen) of the company. He was a vice president at Hughes Aircraft Company and led the team that developed the first geostationary satellite. Castleman is a vice president of the company. She received a master's degree in electrical engineering from the California Institute of Technology and was formerly a deputy assistant secretary of defense for the Clinton administration.

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